LRO-NAC Mass DTM Pipeline.
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Introduction: To demonstrate the feasibility of automated mass production of digital terrain models (DTMs) using the Ames Stereo Pipeline (ASP) software [1,2], we have used ASP to produce over 1000 DTMs from images collected by the Narrow Angle Camera (NAC) on the Lunar Reconnaissance Orbiter (LRO). Due to budget constraints and high processing time, fewer than 300 official LRO-NAC DTMs have been released to date [3]. By developing an automated production pipeline we have been able to more than triple this number while maintaining an acceptable level of data quality.

Methodology: After generating a list of nearly 2000 stereo pairs using PostGIS we began processing them en masse using the NASA Pleiades supercomputer. Automated software fetched the source images fron the NASA PDS and associated LOLA data from the PDS Geosciences Node Orbital Data Explorer (ODE) and its Representational State Transfer (REST) interface [4].

After standard preprocessing using the ISIS software suite [5], the LRO-NAC images were calibrated using ASP tools and the Ceres Sparse solver library [6]. This calibration produced a set of transforms which were applied to the ephemeris data of the input images, improving the relative positiong accuracy between the cameras comprising a stereo pair. A second calibration step used ASP's new *pc_align* tool [7] to improve the absolute position accuracy of the images by comparing the positions of a stereo point cloud to nearby LOLA points.

Before beginning DTM creation each left-right LRO-NAC image pair was combined into a single image by using the ISIS *noproj* tool to transform the images into the same coordinate system. Alignment errors were minimized by the earlier calibration step and any remaining error was mitigated by using ASP's *lronacjitreg* tool to apply a corrective shift. The two merged images that made up a stereo pair were then processed using ASP's stereo processing tools.

For each stereo pair we created a DTM, map projected versions of both input files, and several diagnostic outputs. These outputs included a statistical comparison to the nearby LOLA data to see how closely our output DTMs matched existing terrain data.

Results: We produced over 1000 DTMs using our automated pipeline, significantly more than the number of LRO-NAC DTMs completed to date. Due to point-matching failures, problems with the input images, and other issues, not every stereo pair that was processed resulted in a valid DTM output. To produce 1000 DTMs we had to attempt approximately 1150 stereo pairs, a success rate near 87%. Fortunately, processing failures usually occur early in the DTM creation process and do not cost much computational time.

Comparing our DTMs with LOLA data we found that over 90% of our DTMs have a mean difference of less than 10 meters and 50% have a mean difference of less than 5 meters. One drawback of our fully automated DTM creation process is that the output DTMs have noticeably more artifacts and holes than do similar DTMs created using SOCET-SET followed by manual editing. Approximately 20% of our DTMs had a large enough amount of artifacts to limit their potential usability.

Conclusions: Our DTM creation efforts serve as a demonstration of the potential of fully automated DTM production. As remote sensing capabilities improve and cameras increase in resolution, automated DTM processing methods will increasingly be required to keep up with the stream of input sensor data. We hope that this demonstration also encourages other researchers to use the Ames Stereo Pipeline software. While we plan to continually improve the accuracy of ASP's results, we think that ASP can already make significant contributions to scientific research.

References: [1] Moratto, Z. M.; Broxton, M. J.; Beyer, R. A.; Lundy, M.; and Husmann, K. 2010. Ames Stereo Pipeline, NASA's Open Source Automated Stereogrammetry Software. Lunar and Planetary Science Conference 41, abstract #2364. [2] ASP Development Team. The Ames Stereo Pipeline, February 2011. URL http://irg.arc.nasa.gov/ngt/stereo.
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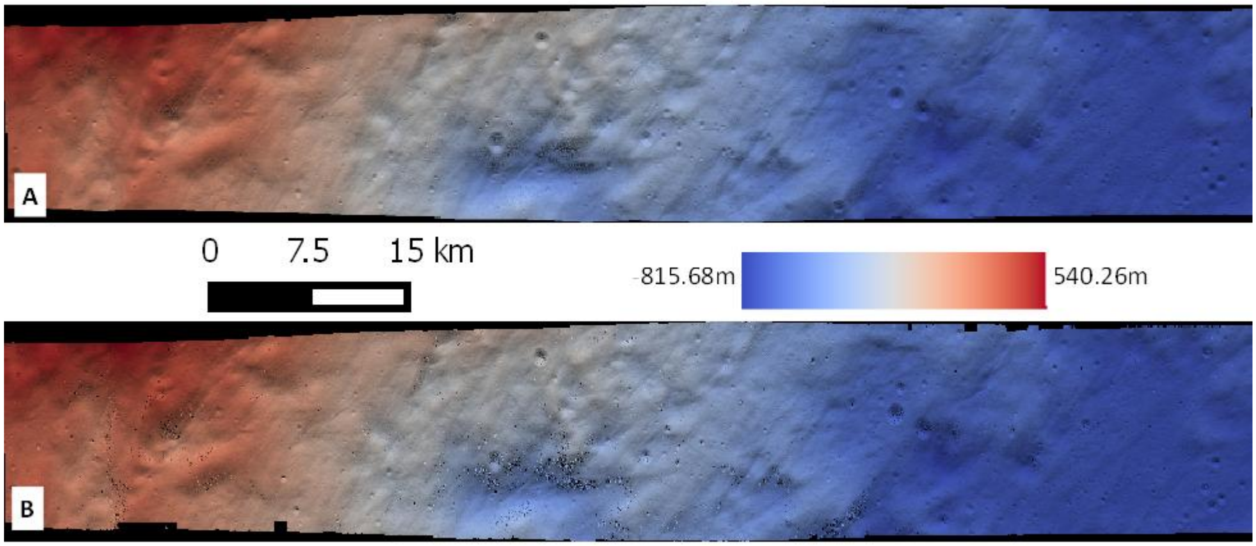
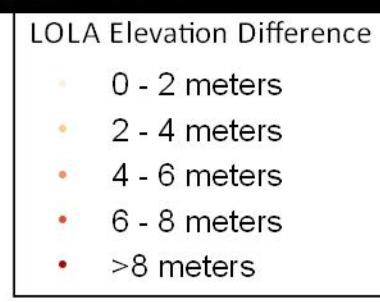
[4] Bennet, Keith. NASA Planetary Data System Geosciences Node's Orbital Data Explorer (ODE) and Granular Data System (GDS) REST Interfaces. URL http://oderest.rsl.wustl.edu/ Sept. 15 2014. [5] USGS Isis Development Team. USGS Isis: Planetary Image Processing Software, February 2011. URL http://isis.astrogeology.usgs.gov/. [6] Sameer Agarwal, Keir Mierle, and Others. Ceres Solver. URL http://ceres-solver.org. [7] Beyer, R. A.; Alexandrov, O.; and Moratto, Z. M. 2014. Aligning Terrain Model and Laser Altimeter Point Clouds with the Ames Stereo Pipeline. LPSC 45, abstract #2902.

Sample results for the ARISTARCHU2 data set





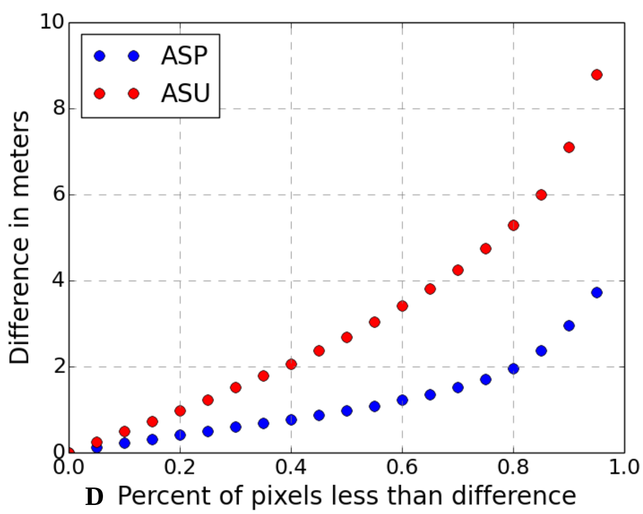


Figure A: Hill-shaded color map of the ASU produced DTM

Figure B: Hill-shaded color map of the ASP produced DTM

Figure C: Map projected image on ASP DTM with distance to each LOLA point overlaid

Figure D: Percentile histogram of ASP and ASU DTM distance from LOLA